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HOW THE WIND BLOWS
in the Forest of Northern Idaho

by

DIVISION OF FOREST PROTECTION

Northern Rocky Mountain
Forest & Range Experiment Station
Missoula, Montana
M. Bradner, Director

—A PROGRESS REPORT SPECIALLY PREPARED FOR USE BY FIRE CONTROL MEN IN THE NORTHERN ROCKY MOUNTAIN REGION—

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J R Davis

June 10, 1941

HOW THE WIND BLOWS IN THE FOREST OF NORTHERN IDAHO

By H. T. Gisborne
In Charge, Division of Forest Protection
Northern Rocky Mountain Forest and Range Experiment Station

Wind is one of the two most powerful factors causing changes in forest fire danger from day to day. In fact many experienced fire fighters believe that wind velocity is equally if not more important than fuel moisture, the other major factor. Hence in measuring fire danger each day and in using these ratings for dispatching men and in determining the suppression tactics best suited to quick control of forest fires, efficiency absolutely demands that the best possible estimates of wind velocity be used.

But wind is not a uniform condition, the same all over a ranger district from valley bottom to mountain top. It is not the same in all fuel types, open grass, timber sale area, or dense virgin forest, and it is not the same even in a single, simple fuel type like grass at a certain instant, say 2 p.m. At that instant the wind velocity may be 20 miles per hour 20 feet above the ground, just as the weather forecaster predicted, but it will NOT be 20 m.p.h. nor perhaps even 10 m.p.h. down in the grass, say, 6 or 8 inches above the ground. At the other extreme of fuel types, under dense timber, the wind may not be more than 2 or 3 miles per hour at the ground level, where forest fires have to be fought, even though the free air movement above the tree tops may be 20 miles per hour or more.

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These great and significant differences between velocities at different heights above the fuels on the ground have been observed and appreciated by the best fire fighters, but the amounts of the differences in different timber and fuel types have not been known. Accurate measurements of some of these differences show that the amounts are even greater than generally believed. Hence, it is obvious that even more attention should be given to these conditions in the future if the right number of men is to be dispatched to each new fire and if the tactics used by the fire fighters are to produce control as quickly and as cheaply as possible.

The accompanying charts have been prepared as an immediate aid to fire control men in the northern Rocky Mountain region whenever they have to estimate how much allowance to make for the reduction of wind velocity caused by forest growth. Ultimately it will be necessary, of course, to have similar sets of charts for low brush, for younger stands of trees shorter and more dense than the particular stand studied, and for older, over-mature stands of still different composition and density. In the meantime the available data, when applied to forests in the 80- to 100-year age class which are of about the density and composition indicated by the photograph, may be used as a first guide. Incidentally, this timber stand is more dense than indicated by the photograph of the tower. This picture was purposefully made through the most open spot or lane that could be found. The cedar understory in this stand should be noted, as it has an undoubted effect in reducing ground-wind velocities.

The most outstanding and useful fact shown by the accompanying charts is that even during the windiest hours of the windiest day, typified by recent fire seasons, a fire on the ground under such a timber canopy will NOT be greatly affected by the wind, because that ground-wind will seldom exceed a sustained velocity of 1½ miles per hour.[1/] If men can reach such a fire before it gets up into the crowns of the trees, where the wind is greater, the fire fighters will not have to combat a very fast rate of spread. Once the smoke-chaser reaches such a fire the tactics clearly called for are first to hold that fire on the ground, and, second and last, to get a fire line around it. Line building will be completely wasted, of course, if this fire goes up one moss-covered or limby tree and gets into the free air velocities that sustain a crown fire and start a "run" or "blow-up." But held down to the ground level, or at least to within a few feet of the ground, a fire under dense timber will be affected by such an extremely light wind, not counting that created by the fire itself, that its ground spread will not be fast. This will be true even on a class 5 day when fuel moistures at standard inflammability stations are down to 5 or 6 percent unless there is an exceptional volume of dead fuels on the ground beneath the timber canopy. With assurance that the fire will not crown, moderate rate of spread on the ground can then be controlled by line

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1/ The "corrected" velocity may be somewhat higher than this due to lack of sensitivity of "standard" 3-cup anemometers to air movements of less than 1 m.p.h. However, drifts of air that will not turn the cups of such an instrument are of little, if any, significance to fire behavior.

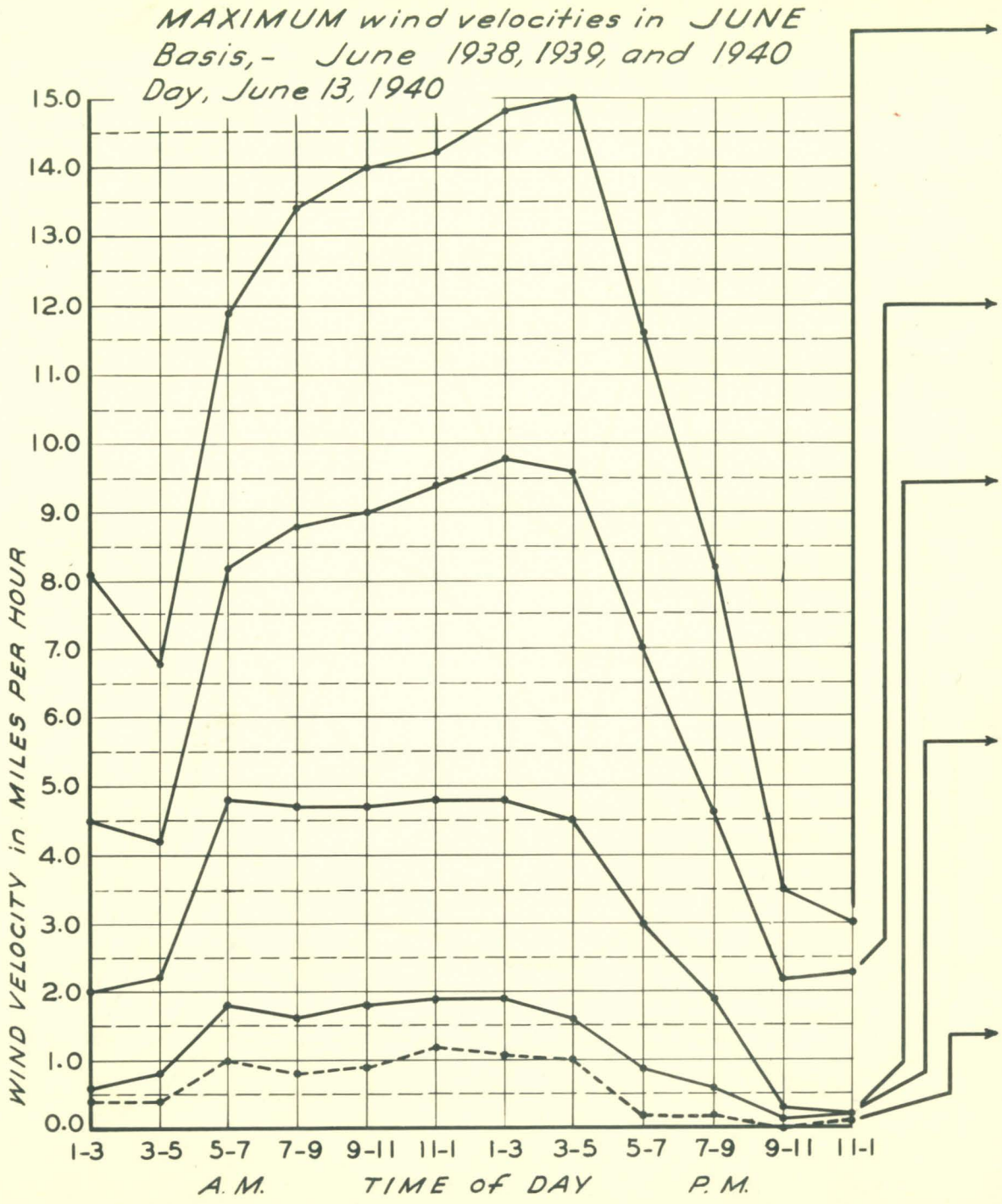
construction and the total cost plus damage held to a true minimum.

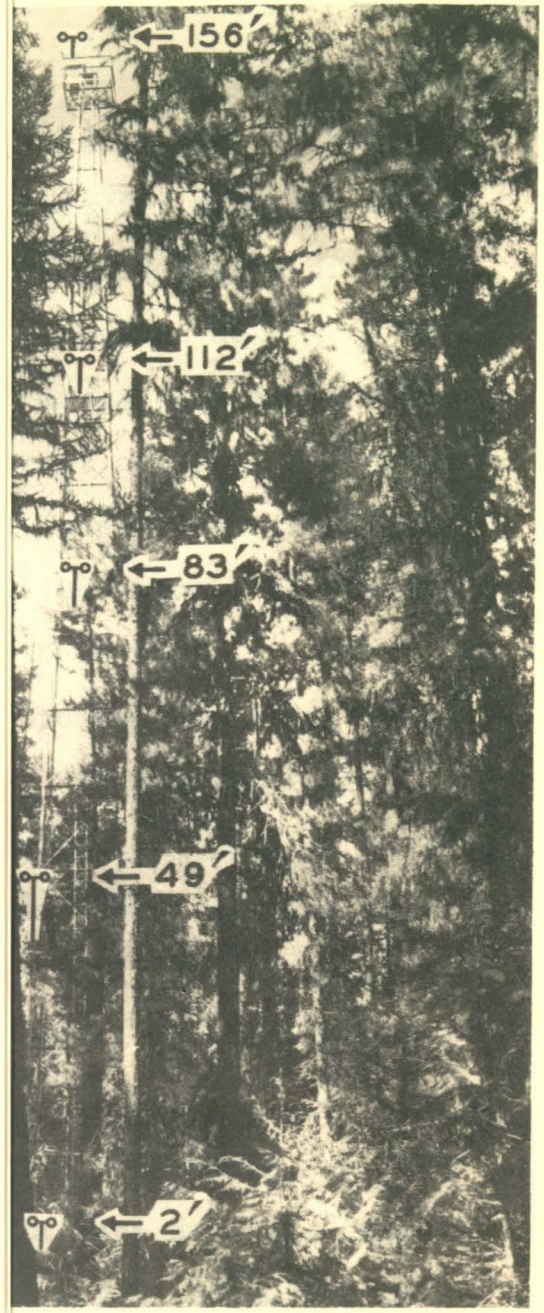
For the windiest day in June 1938, 1939, or 1940, the windiest day in July 1938-1940, and the windiest in August, the three charts reproduced for "maximum" velocities show no definite pattern beyond an increase during the daylight hours. Even this, however, is known not to be true on mountain tops where a lull usually occurs between 9 and 11 a.m., and where the maximum velocity is often reached during the night. These three charts show that in the valley bottoms wind maxima may occur at any time between 7 a.m. and 7 p.m. One danger is apparent in two of the charts for maximum velocities on July 24, 1938, and August 28, 1939, respectively. In these two cases, measurements of wind velocity made between 7 and 9 a.m. P.S.T., would have been seriously misleading as indices of the fact that these were to be exceptionally windy days. Temporary lulls occurred at 7 to 9 a.m. on both of these days, yet this is the time at which the first measurements of the day are always made at forest fire danger stations. "Standard" measurements at 8 a.m. are obviously not always dependable as indices of the type of wind-day that is to follow.

One significant condition, revealed particularly by the three charts of average velocities for June, July, and August, is the decrease in velocity at the ground level after 1 p.m. While this decrease is not marked until after 3 p.m. still the records show clearly that at least there was not an increase taking place at the ground level

even though the free air movement, up above the tree tops, actually did and generally does increase between 1 and 3 p.m. Apparently, fire dispatchers should remember that as a general rule, unless the day is exceptionally windy, the peak of the wind effect at the ground level under certain timber types will be passed by 1 p.m. This, coupled with improvements in temperature and humidity after 3 p.m., to be mentioned later, definitely indicates the possibility of safely "taking more chances" with ground fires under timber during the late afternoon. "Taking chances safely" is, of course, a common prerequisite to fire control at minimum cost, and intelligent application of proved principles is the only safe basis for taking such chances.

All six charts for "average" and "minimum" wind-days also serve to demonstrate that on all average and less windy days wind is a factor of extremely minor importance on the ground beneath a moderately dense forest canopy. On average days that part of this ground-wind which can be measured with standard anemometers is usually about three-fourths of one mile per hour, or less. On the quietest days it seldom exceeds one-half mile per hour. The three charts for "average" velocities also show that there is very little difference from month to month, June through August, of the ordinary inflammability season such as this region experienced in 1938, 1939, and 1940. No one month appears to be consistently more dangerous from the wind standpoint than any other of the three studied; all experience a peak of free air movement between 11 a.m. and 3 p.m., and no marked decrease in wind up above the forest canopy should be expected until after 5 p.m. in this region.





-weather tower
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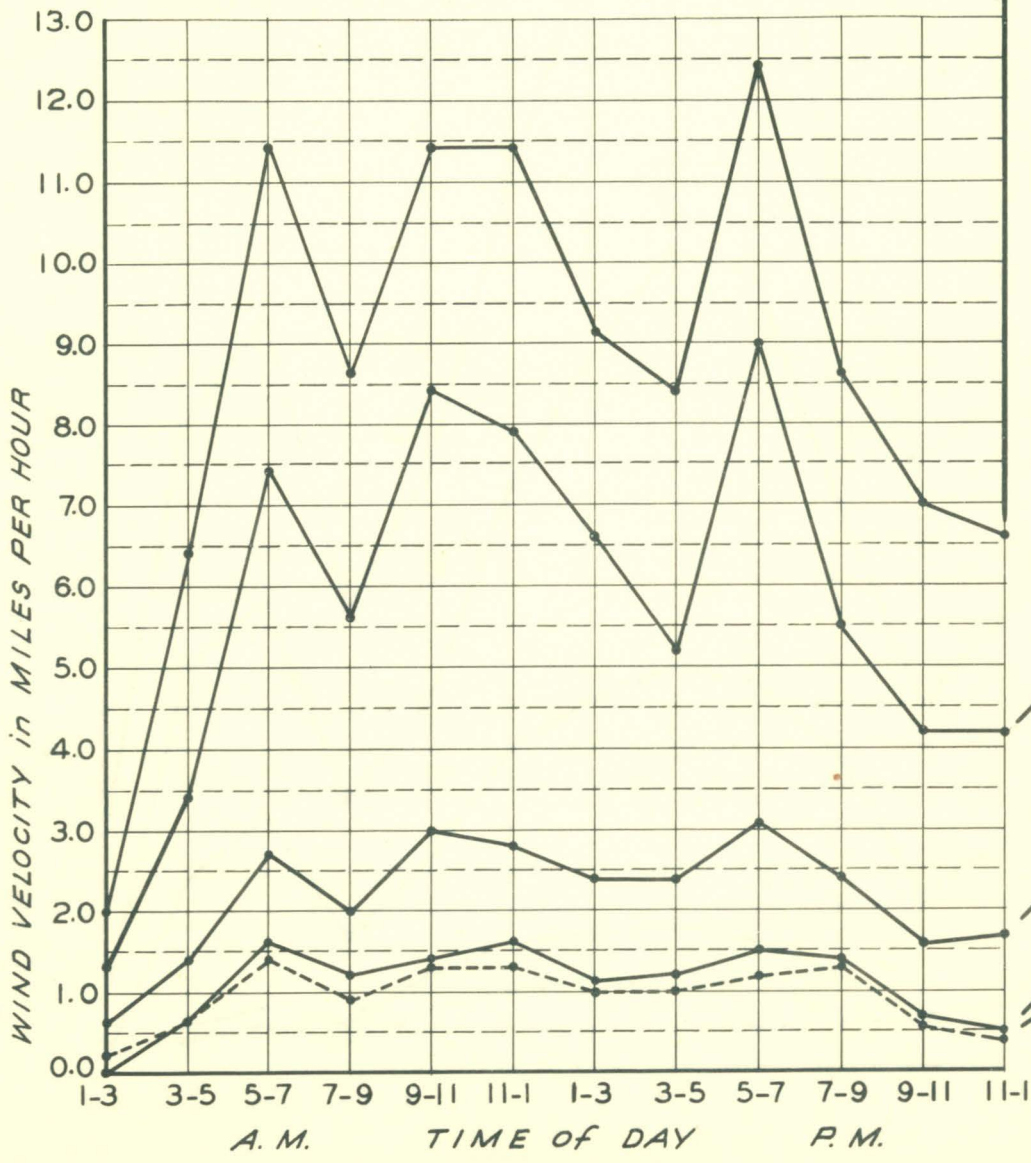
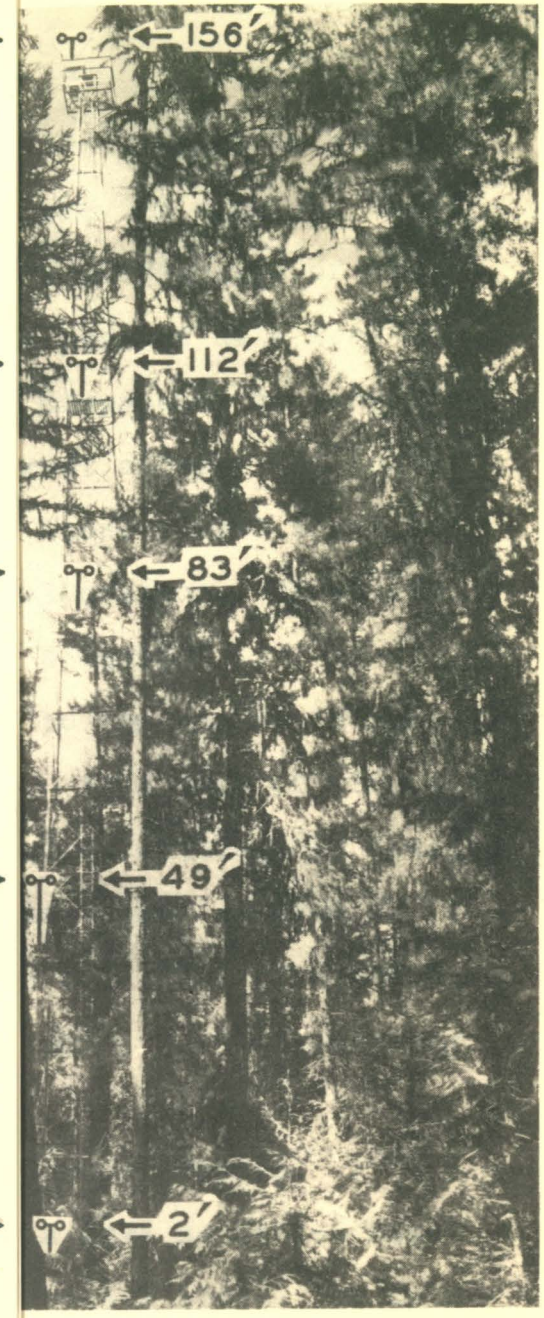
MAXIMUM wind velocities in JULY
Basis,- July, 1938, 1939, and 1940
Day, July 24, 1938





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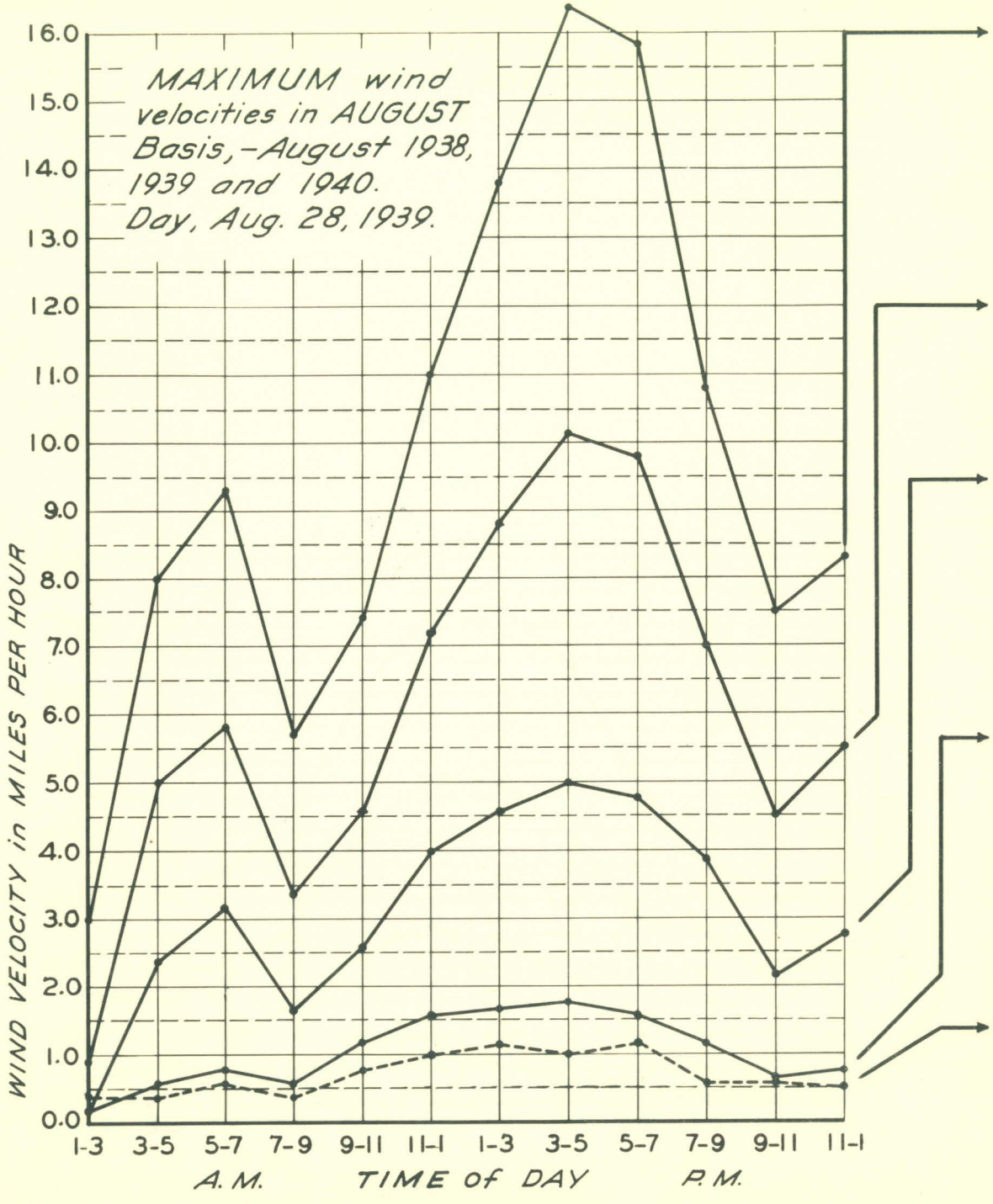

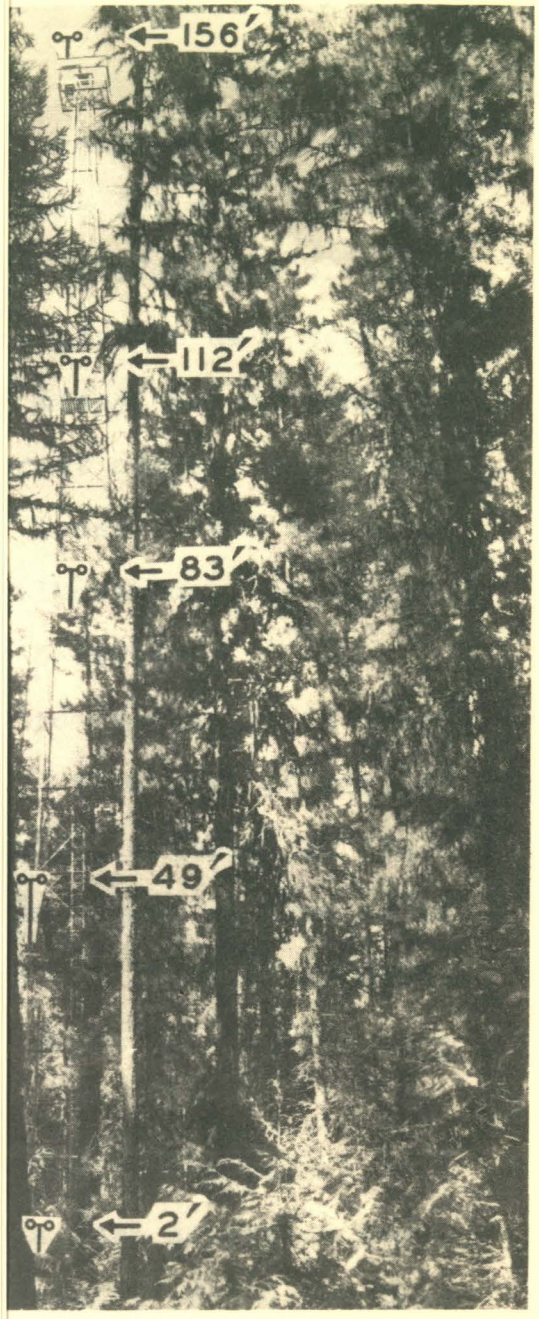

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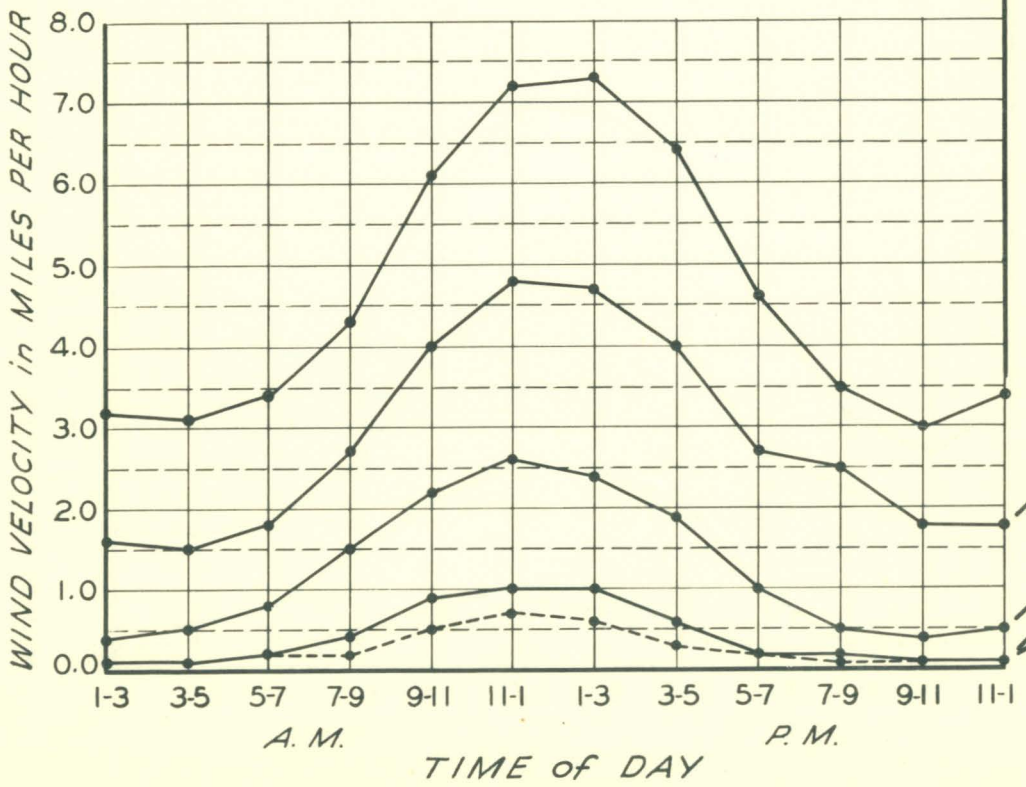
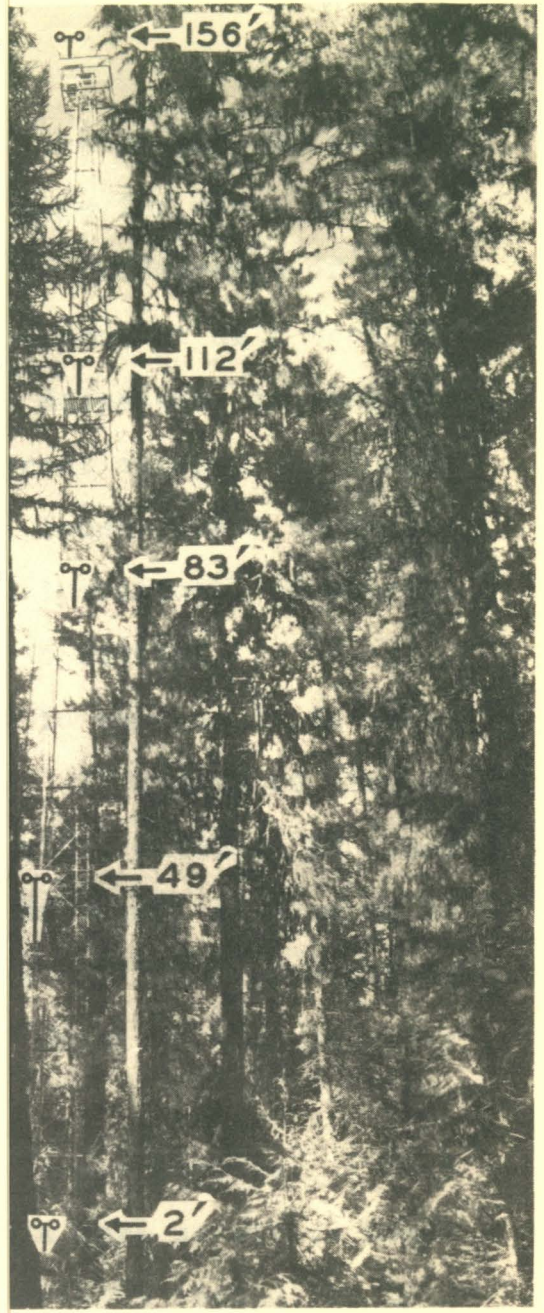
AVERAGE wind velocities in JUNE
Basis,- June 1938, 1939, and 1940





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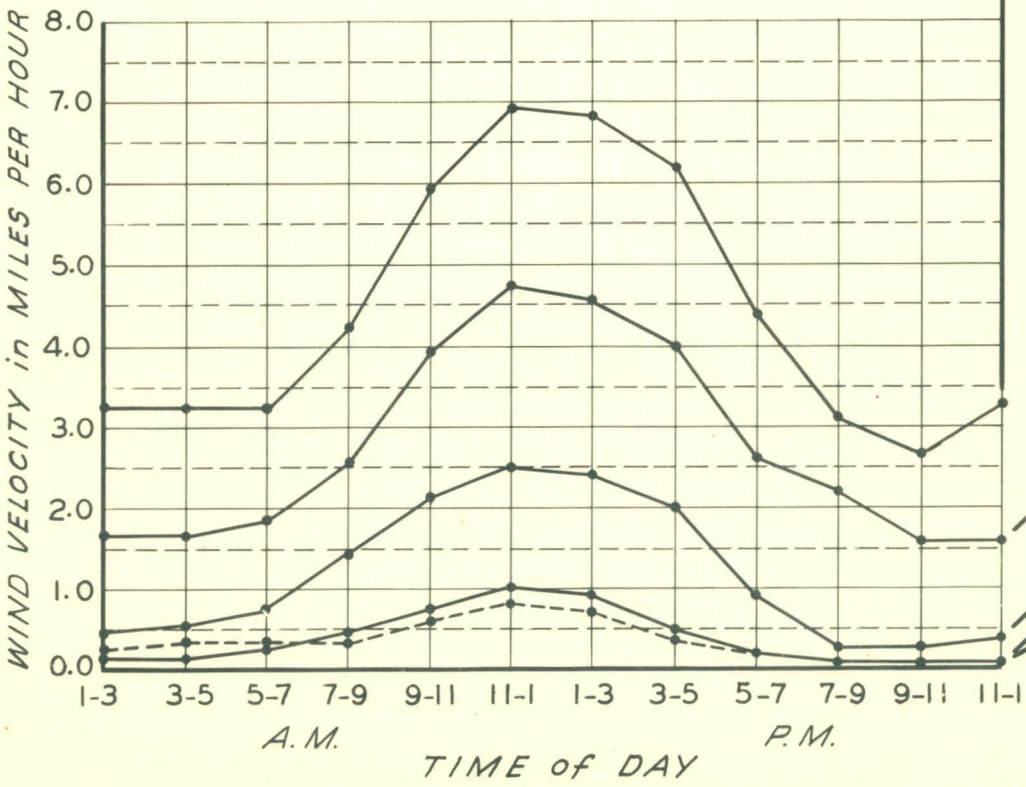
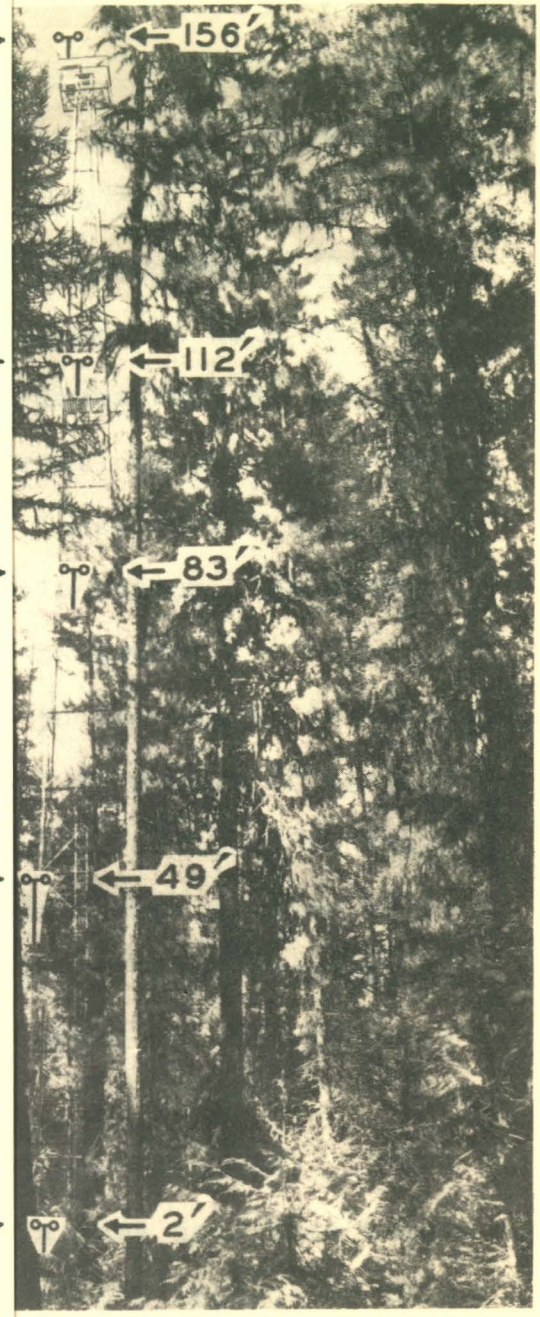
AVERAGE wind velocities in JULY
Basis, - July 1938, 1939, and 1940





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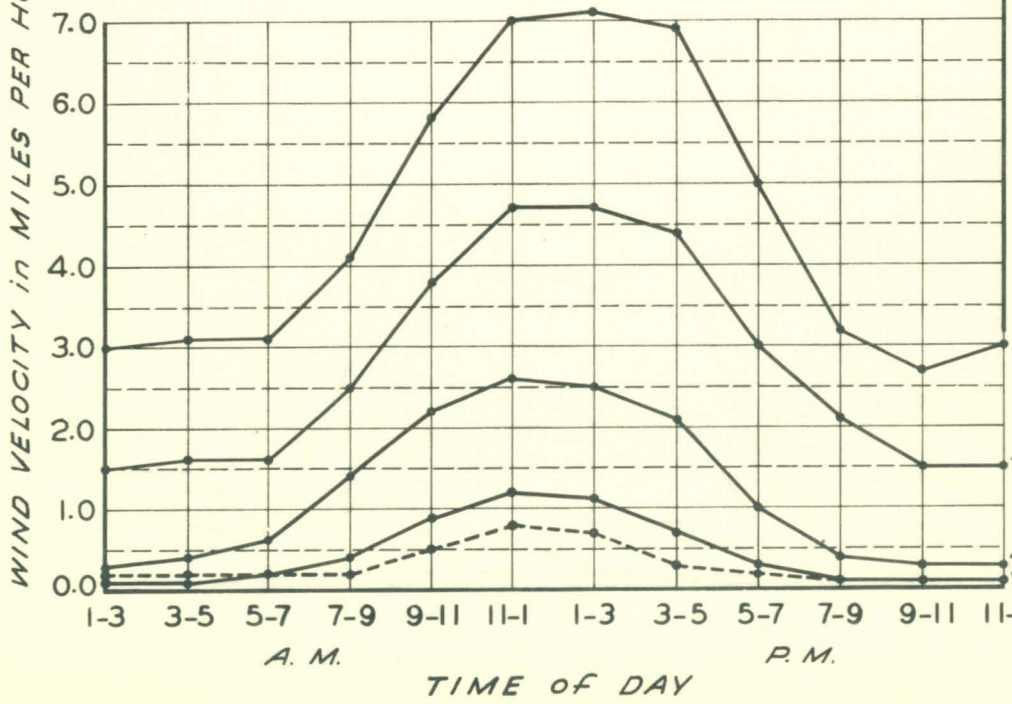
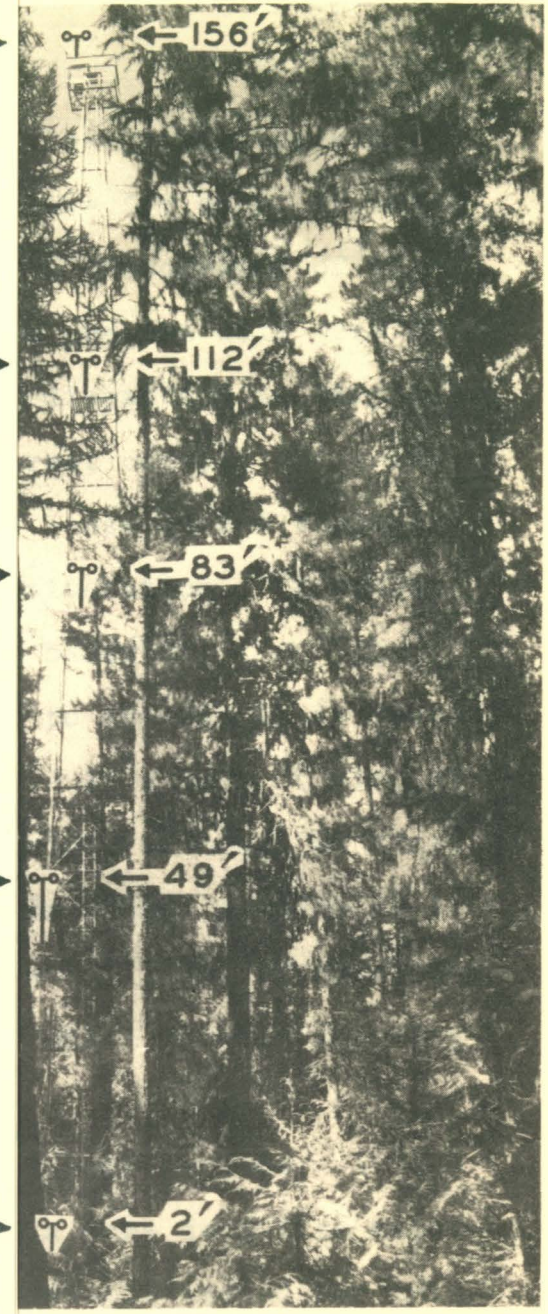
AVERAGE wind velocities in AUGUST
Basis,- August 1938, 1939, and 1940





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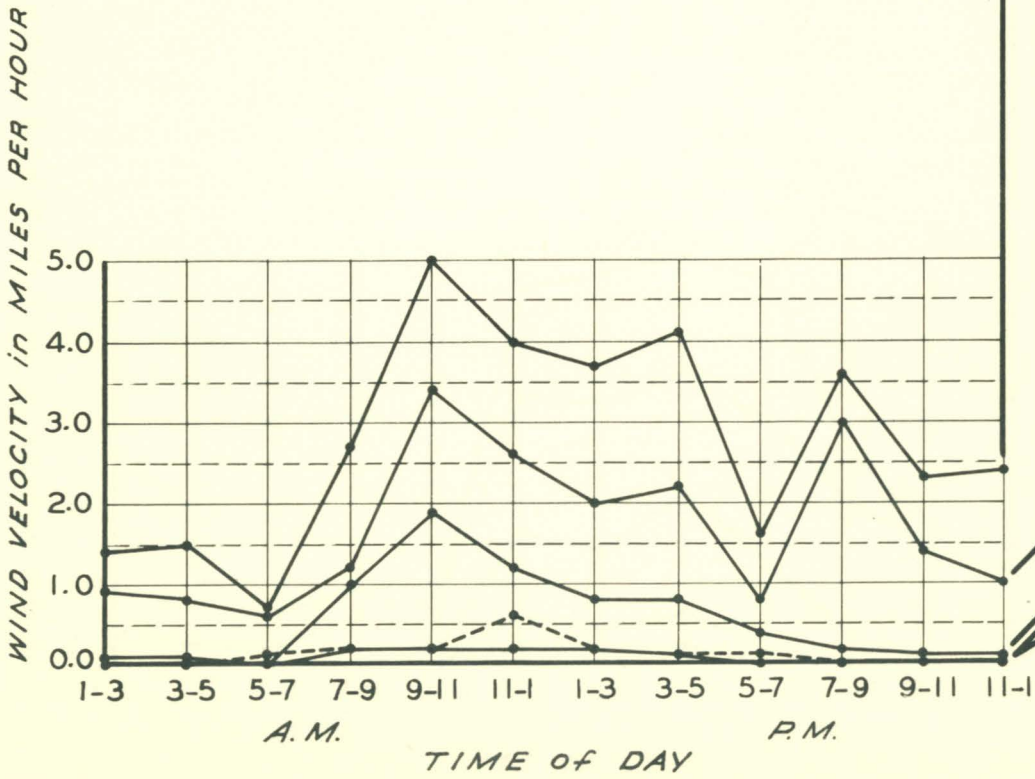
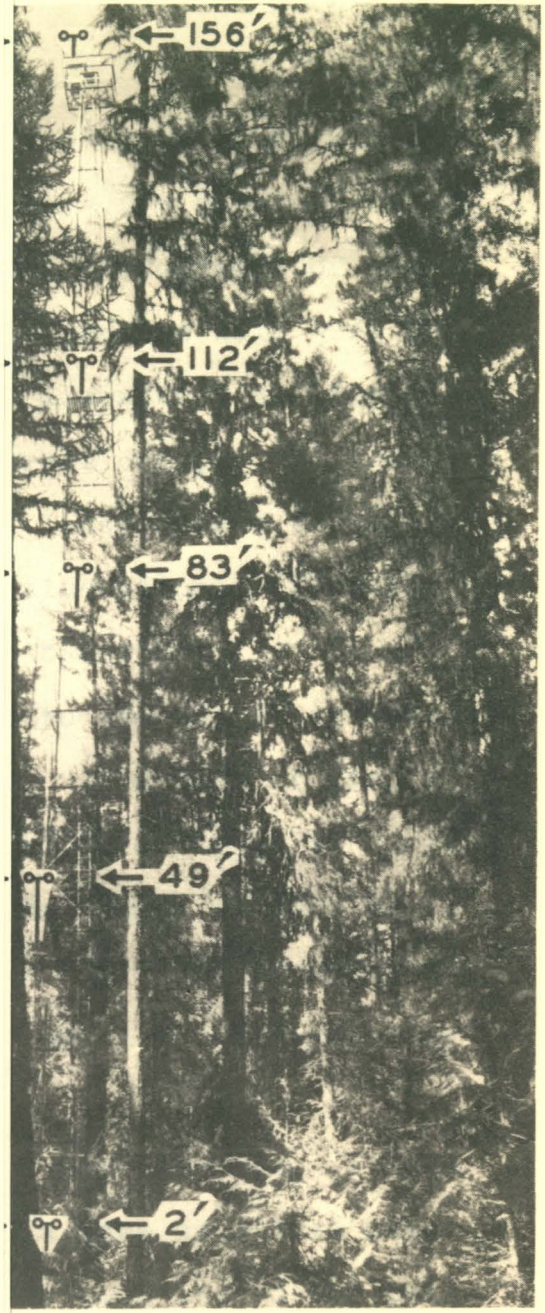
MINIMUM wind velocities in JUNE
Basis,- June 1938, 1939, and 1940
Day, June 23, 1938





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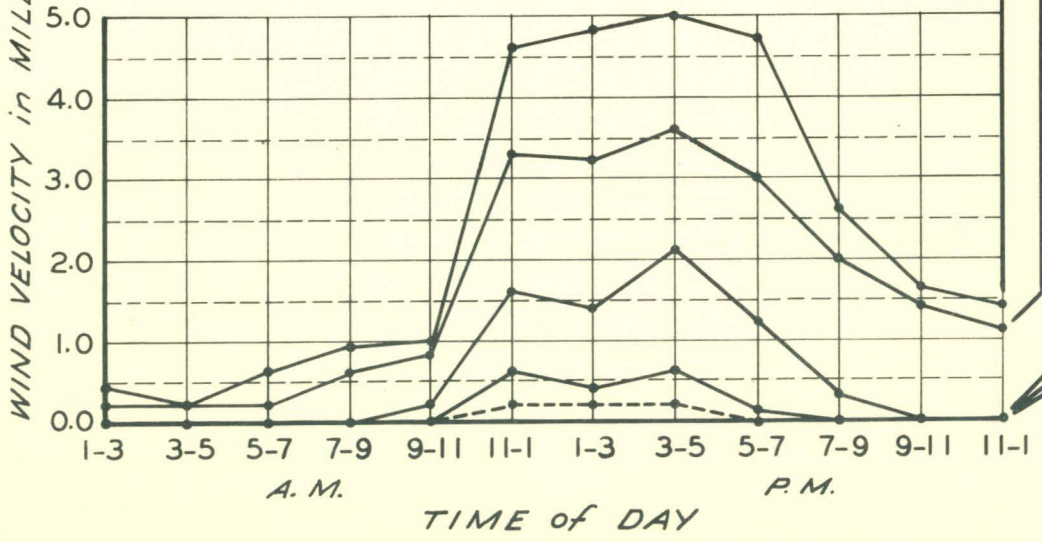
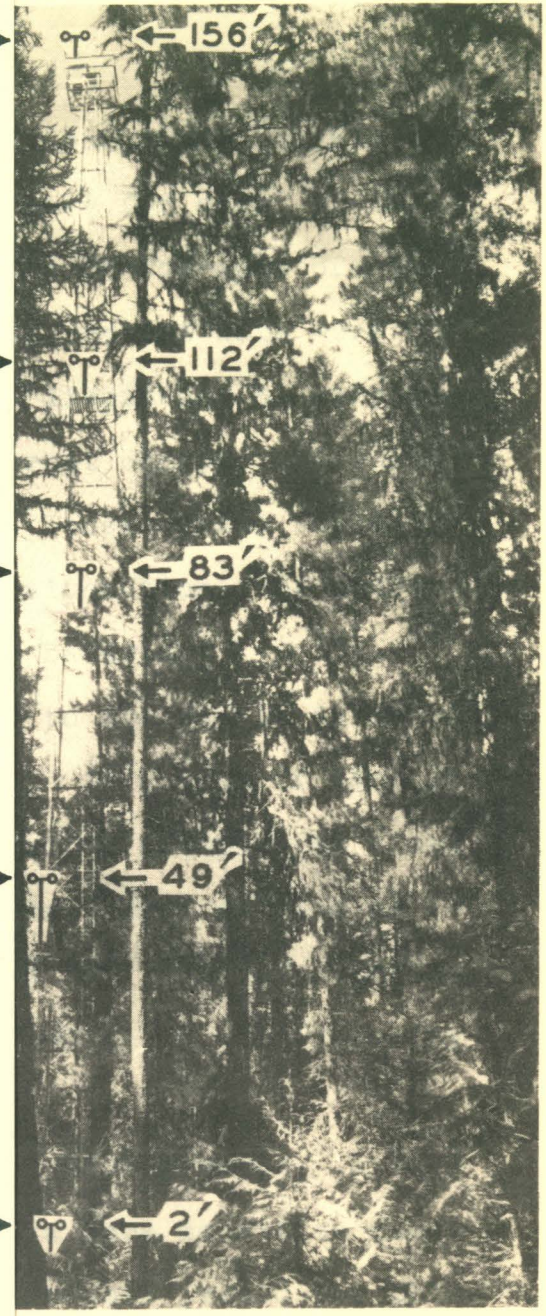
MINIMUM wind velocities in JULY
Basis,- July 1938, 1939 and 1940
Day, July 27, 1940





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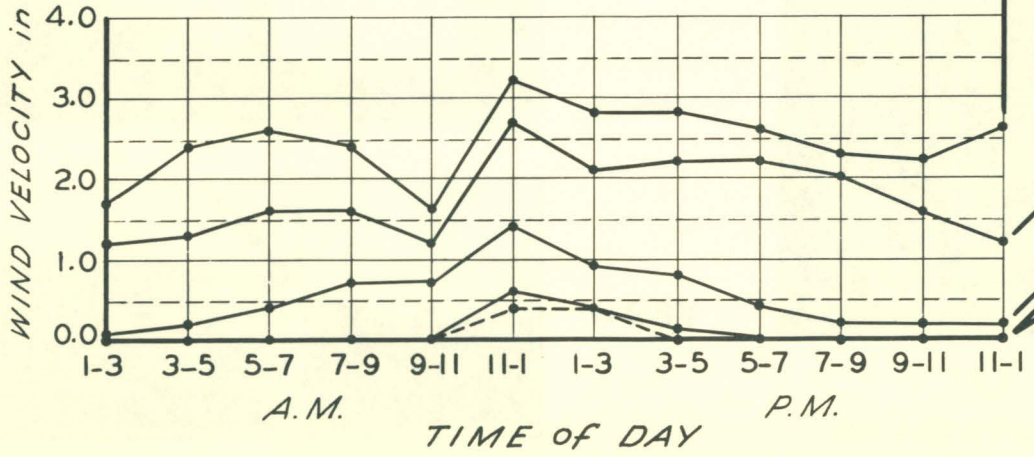
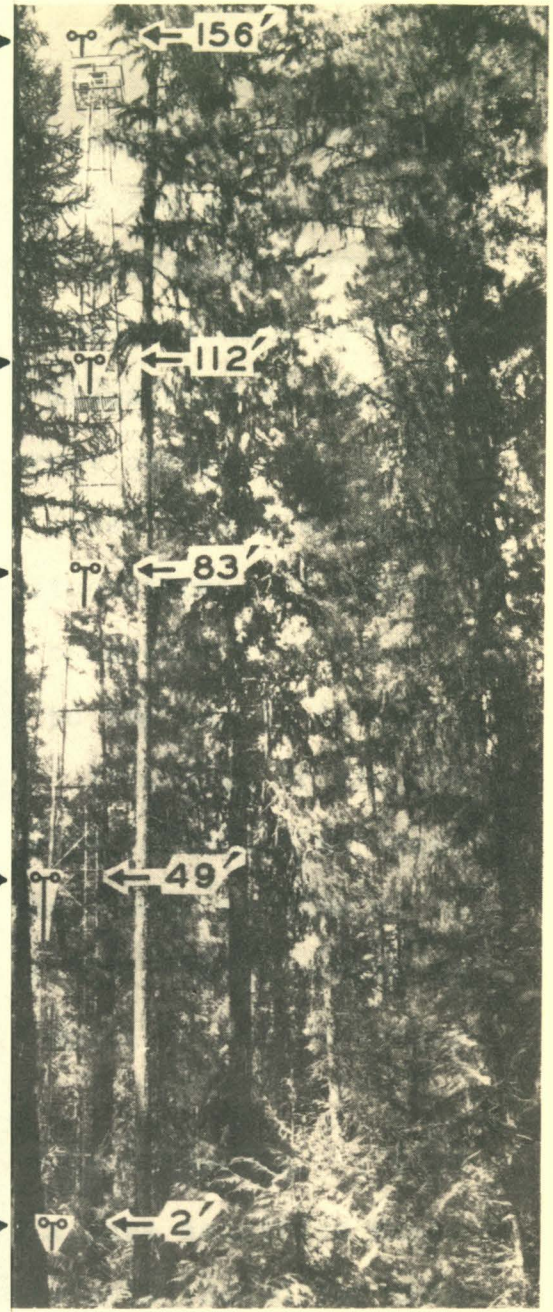
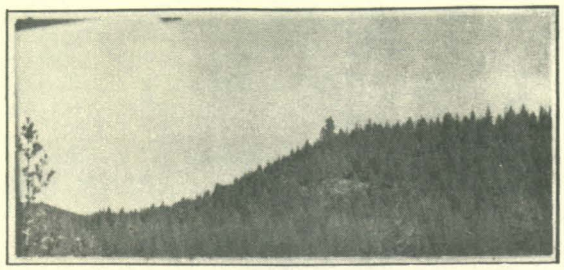
MINIMUM wind velocities in AUGUST
Basis, - August 1938, 1939, and 1940
Day, August 24, 1940





'– weather tower
er Experimental Forest

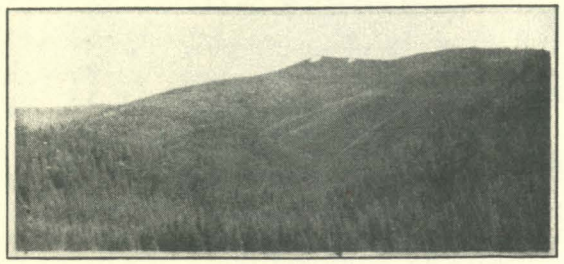
THE SURROUNDING COUNTRY AS SEEN FROM THE 112 FOOT PLATFORM ON THE TOWER



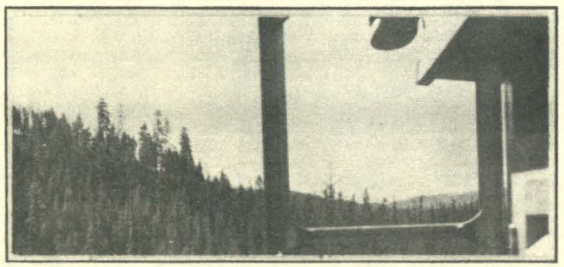
Looking toward the

NORTH

Note the tallest tree at extreme left

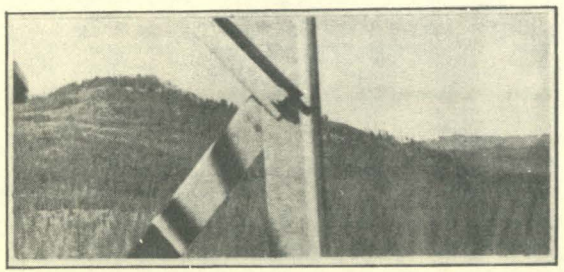


EAST

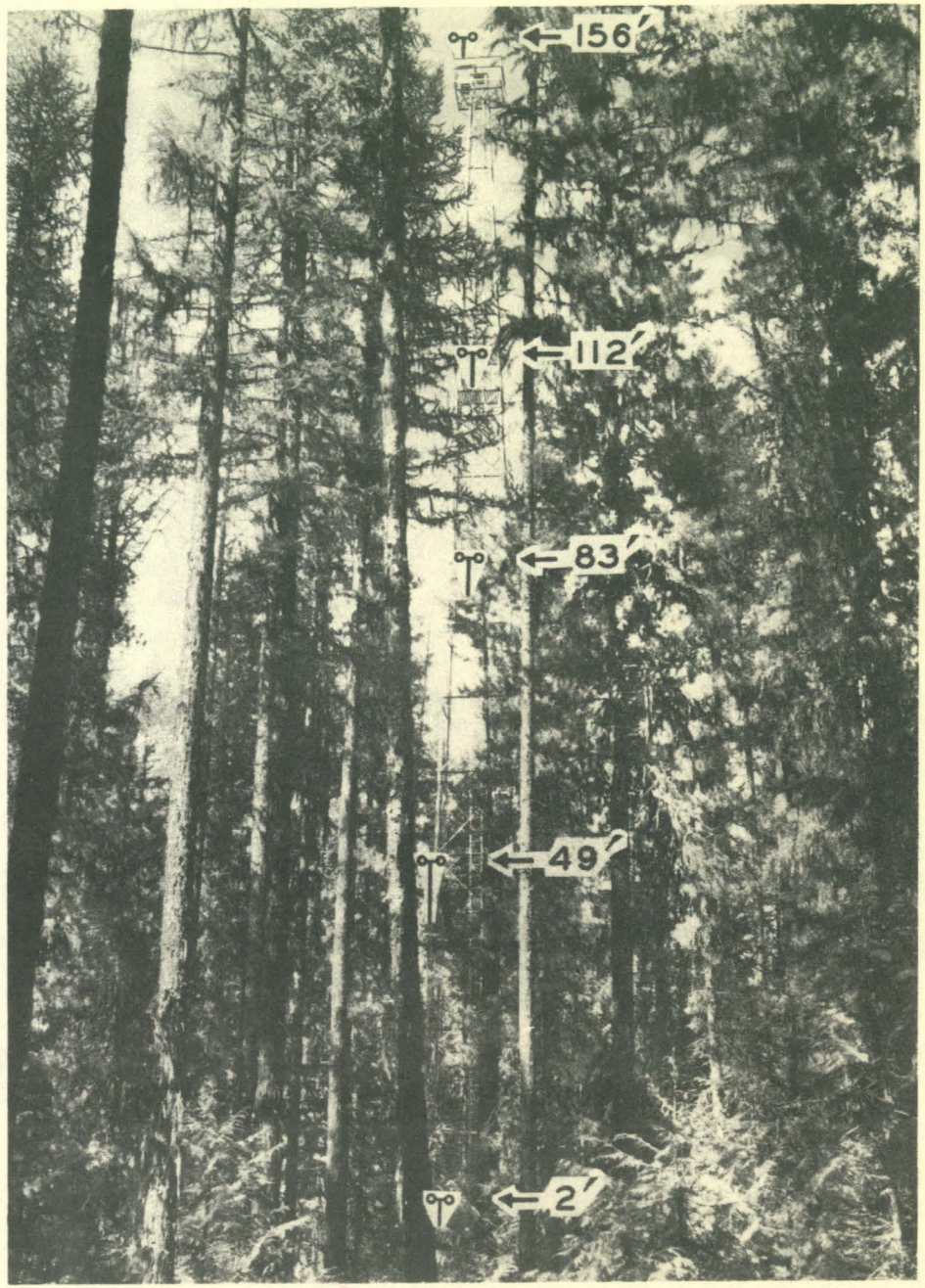


SOUTH

15 miles to ridge in background



WEST



The forest-weather tower on the Priest River Experimental Forest

Caution

These charts cannot be used blanket-wise in all types of topography, on all exposures, or at all elevations, of course. How much allowance to make for each of these factors still remains a matter of judgment. By reference to the photographs of views to the north, east, south, and west from the spot at which the present data were obtained it should be possible, however, for the experienced fire dispatcher to vary his additional allowances. The fuel type on the ground under the forest canopy, the consequent volume of heat generated by a fire, and the presence of loose-barked snags, and limby, mossy, and "fuzzy" trees also must be given detailed consideration, of course, in judging fire behavior. Wind is not the sole control of fire behavior.

Furthermore, there are several kinds of "wind" according to the way it is measured—by the second, minute, hour, two hours, afternoon, or day. If a mass of air, 25 miles long, flows past a station in one hour that is a 25 m.p.h. wind, although at times the rate of flow may be as fast as 45 miles per hour and at other times as slow as 10 miles per hour. Wind, or the flow of air, is not as constant as the flow of water in a stream. Hence, it is always necessary to note the period for which a wind-velocity measurement is intended to apply.

In the preceding graphs the wind velocity is shown for 2-hour periods, 1 to 3 a.m. or the average around 2 a.m., 3 to 5, 5 to 7, etc. This is a more sensitive measure than is used in fire danger rating or in the fire-weather forecasts issued for this

region, both of which are intended to express the "average afternoon wind velocity," say, from noon to 5 p.m. P.S.T. While this period includes the windiest hours, as shown by the preceding charts, the diagrams showing velocity differences by 2-hour periods reveal some of the common variations that must be expected. Such variations are well known to experienced fire control men who appreciate the fact that a myriad of charts would be necessary to illustrate all possible variations, and that a myriad of cases would confuse rather than clarify the general principles developed here.

Possibly the most common "bone of contention" concerning the data as published here for 2-hour periods will be the argument that on June 13, 1940, for instance, when the record shows a velocity of 15 m.p.h. for the period 3 to 5 p.m., there undoubtedly were gusts significant to fire behavior of much greater velocity than 15 m.p.h. This is an important fact which should be clearly recognized in using these data.

There is no contention that this is not the case. Measurements are available showing that when the wind is averaging 15 m.p.h. short gusts of 25 m.p.h. followed by lulls to as low as 5 m.p.h. should be expected. Charts could be prepared showing these absolute maximum and minimum velocities, which usually last for less than a minute or a minute and a half, but the spread of such data would be so great as to cause an immediate demand for more specific figures. The data by 2-hour periods are believed to be most suitable at present. When used with this caution in mind they serve to show major differences between days and parts of days that are basically important in providing adequate fire control at minimum cost.

Normal Wind Gradient

For the information of those interested in further details concerning wind velocities, table 1, prepared by Professor Gardner Emmons of New York University, is included. This table shows the significant increase in wind velocity with increasing height above ground in the open, unobstructed by tree growth of any kind, and over level ground where the topographic influence also is eliminated.

Table 1.--Comparison of velocity equivalents corresponding to various heights above level ground free from obstructions

Height above ground		
8 feet[1/]	20 feet[2/]	66 feet[1/]
Limits of velocity (statute miles per hour)		
0 - 1	0 - 1	0 - 1
1 - 2½	1 - 3	2 - 4
3 - 5½	4 - 7	5 - 9
6 - 9½	8 - 11	10 - 14
10 - 14	12 - 16	15 - 20
15 - 19	17 - 21	21 - 26
20 - 24	22 - 27	27 - 33
25 - 30	28 - 33	34 - 41
31 - 36	34 - 40	42 - 49
37 - 42	41 - 48	50 - 59
43 - 49	49 - 56	60 - 69
50 - 58	57 - 65	70 - 80
Above 58	Above 65	Above 80

1/ Values computed from Hellman's formula.
2/ These are the standard values by international agreement

This table shows two facts not generally appreciated: (1) That to be fully comparable between different stations wind velocity MUST be measured at a standard distance above ground. (2) That 20 feet or 6 metres above ground is the standard as adopted by the International Meteorological Committee. It is obvious from this table, for instance, that there is no real difference between a 15- to 20-mile per hour wind reported from an instrument on a building or tower 66 feet above ground and a 10- to 14-mile per hour report from an anemometer 8 feet above ground, all other things being similar. As will be noted in figure 2-20 of Part Two of the Forest Service Handbook of Fire Control Equipment, an exposure of 20 feet above open, level ground has long been the standard exposure for fire-weather anemometers used by the Forest Service.

Forecasts

All of these facts and one other must be considered by fire control men whenever they use Weather Bureau forecasts of wind velocity. This additional fact is that the Weather Bureau does not specify the exact height above ground at which their measurements are made and their forecasts are intended to apply. As their predictions are for free air movement, unimpeded by character of ground surface or vegetative growth, it is obvious that corrections must be made when these forecasts are applied to fire behavior as influenced by wind velocity amidst the fuels on the ground. This was first done for the northern Rocky Mountain region by the small cards prepared in 1935 on the basis of special studies by George M. Jemison describing the "Northern Rocky Mountain

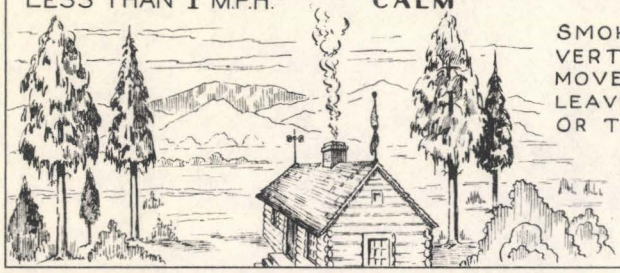
NORTHERN ROCKY MOUNTAIN SCALE OF WIND VELOCITY

FOR USE IN ESTIMATING WIND VELOCITIES IN WESTERN MONTANA AND NORTHERN IDAHO

NORTHERN ROCKY MOUNTAIN FOREST + RANGE EXPERIMENT STATION

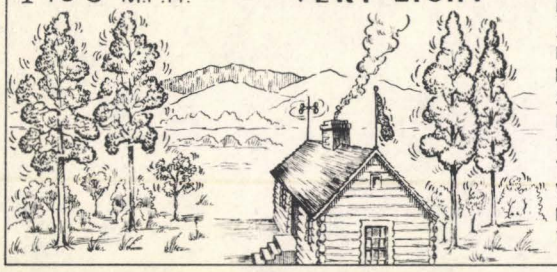
WIND CLASS	TERMS USED IN U.S.W.B. FORECASTS	EFFECTS OF WIND

LESS THAN 1 M.P.H. **CALM**



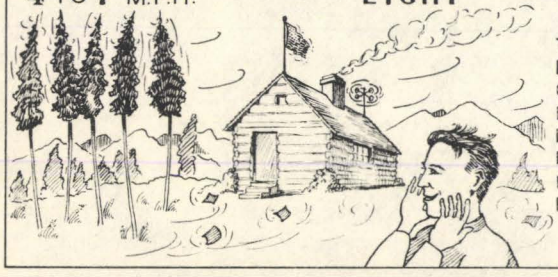
SMOKE RISES VERTICALLY; NO MOVEMENT OF LEAVES OF BUSHES OR TREES.

1 TO 3 M.P.H. **VERY LIGHT**



LEAVES OF QUAKING ASPEN IN CONSTANT MOTION; SMALL BRANCHES OF BUSHES SWAY; SLENDER BRANCHLETS AND TWIGS OF TREES MOVE GENTLY; TALL GRASSES AND WEEDS SWAY AND BEND WITH WIND; WIND VANE BARELY MOVES.

4 TO 7 M.P.H. **LIGHT**



TREES OF POLE SIZE IN THE OPEN SWAY GENTLY; WIND FELT DISTINCTLY ON FACE; LOOSE SCRAPS OF PAPER MOVE; WIND FLUTTERS SMALL FLAG.

8 TO 12 M.P.H. **GENTLE**

TREES OF POLE SIZE IN THE OPEN SWAY VERY NOTICEABLY; LARGE BRANCHES OF POLE-SIZE TREES IN THE OPEN TOSS; TOPS OF TREES IN DENSE STANDS SWAY; WIND EXTENDS SMALL FLAG; A FEW CRESTED WAVES FORM ON LAKES.

13 TO 18 M.P.H. **MODERATE**

TREES OF POLE SIZE IN THE OPEN SWAY VIOLENTLY; WHOLE TREES IN DENSE STANDS SWAY NOTICEABLY; DUST IS RAISED IN ROAD.

19 TO 24 M.P.H. **FRESH**

BRANCHLETS ARE BROKEN FROM TREES; INCONVENIENCE IS FELT IN WALKING AGAINST WIND.

25 TO 38 M.P.H. **STRONG**

TREES ARE SEVERELY DAMAGED BY BREAKING OF TOPS AND BRANCHES; PROGRESS IS IMPEDED WHEN WALKING AGAINST WIND; STRUCTURAL DAMAGE, SHINGLES ARE BLOWN OFF.

DEEMER

Scale of Wind Velocity." The wind effects given by this card form and shown symbolically by the illustrated wind classes "calm" to "strong" issued in 1939 actually apply to velocities measured at 8 feet above level, unobstructed ground for periods of one or two minutes. A copy of these illustrations of wind classes is included here as an aid to fire guards in estimating wind velocities when no instrument is available for measurement. Velocities reported on this basis should be considered as at 8 feet above ground level and of short-period duration. At the international standard height of 20 feet, these velocities would be greater by the amounts shown in Professor Emmons' tabulation.

Temperature and Humidity

Some other measurements made at various levels on the weather tower at Priest River indicate one other effect of forest canopy of great significance to fire dispatchers and to smoke-chasers. These measurements reveal a condition not previously known and never before reported, so far as has yet been determined. This is, that within two feet of the ground level in this particular timber type, the peak of fire danger due to temperature and humidity is reached between 1 and 3 p.m. and has passed after 3 p.m. on the average day in June, July, or August. After 3 p.m. air temperature is decreasing and relative humidity is normally rising, hence fuels within two feet of the ground are becoming less inflammable.

This is not at all the case on clearcut or clean-burned areas and may not be true under the canopy of other species of timber or of other densities and age classes. Three seasons of measurements in the particular stand studied, however, have consistently shown the important fact just stated: by 3 p.m. the peak of the fire day has passed. Undoubtedly this can and should be considered by fire dispatchers in judging the speed and strength of attack needed by new fires known to be burning on the ground beneath a timber canopy similar to that shown by the photograph of the weather tower. The probable behavior of such fires should not be judged as likely to become worse and worse up to 5 or 6 p.m. as is the case with fires "in the open." Instead, it is possible to take chances with more safety after 3 p.m. if the fire is on the ground beneath moderately dense timber, and if the fire fighters can be depended upon to hold it there. This is not true, however, very far above the ground level even under dense timber. At 45 feet above ground, temperatures and humidities do not commence to become favorable until after 5 p.m., and up in the free air at the 156-foot level, 50 to 75 feet above the tree canopy, temperatures and humidities do not become materially more favorable until after 7 p.m.

Summary

These initial findings from this research project are being released now merely as preliminary indications. They are so significantly useful, however, that they are offered prior to the thorough checking of instrumental sensitivity and accuracy being

made during the 1941 season. As soon as these checks are completed charts for temperature and humidity also will be prepared and made available similar to those here offered for wind velocity. By that time additional wind data may include higher velocities than any so far recorded and may comprise a sufficient basis for derivation of the wind gradient formula for this timber type similar to Hellman's formula for the gradient over open, level ground. When that formula is available for every significantly different timber type, then one more quantitative measure will be added to those already in use to aid fire control men in applying the science of forest pyrology.

WHO DID IT

Directors of research, primarily responsible for lines of work pursued and for the funds allotted to particular research projects, seldom receive due credit for their part in these projects. Likewise, the "temporary field assistants," employed for only 3 or 4 months each summer and changing from year to year on each project, often may feel that while they actually did most of the routine work the published results conspicuously ignore their personal contributions.

On the Priest River Experimental Forest in northern Idaho one "long time" research project is under way, which, as it produces results, most certainly is to be credited to many people. In 1934 Director Lyle F. Watts advocated the construction and allotted the funds to construct a meteorological or "weather" tower, 150 feet in height, not out in the open but in the midst of a dense stand of timber then about 80 to 100 feet tall. Ed Quinn, a local jack-of-all-trades, aided by a few CCC boys, and under the general supervision of Station Superintendent J. B. Thompson, erected the steel for this tower without mishap, and without cutting a single tree. The result was an unexcelled opportunity to measure atmospheric conditions from the ground beneath this forest canopy, up through the crowns of the trees, and into the free air at least 50 feet above the tallest tree, exactly as Director Watts had intended.

Continuously recording instruments essential to such a study are exceedingly expensive, especially if they are to provide the accuracy necessary to show true differences between temperatures, humidities, and wind velocities under the conditions to be measured here. This high cost delayed progress because, beginning in 1936, funds for fire research became less and less available during succeeding years. Each year, however, by pinching funds from other projects, a few more instruments could be purchased for this one. Special instrument shelters also had to be built to house the maximum and minimum thermometers and the hygrothermographs. George M. Jemison, then assistant forester on fire research, selected the levels at which to measure, and designed the special instrument shelters. Sy Belden, an ERA carpenter; then built the shelters. Trial measurements were made and the techniques steadily improved. By the spring of 1938 this weather tower and its many instruments were ready to work as a unit.

That summer the temporary field assistant, Leo Shames, previously an instructor in a school of forestry, backpacked the carefully calibrated instruments up the almost vertical steel ladder to each of the four platforms, then climbed that 150-foot, leg-taxing ladder three times each week for

3 months to change charts and to check the accuracy of each instrument at each level. The next summer Jack Oliver, relieved occasionally by Bert Naiman and George Weyermann, repeated this process. In 1940 Naiman did nearly all the work with assistance on Sundays and holidays from D G McKeever. Each fall the instruments had to be brought down and cleaned. Each spring Vern Cline recalibrated them all. Supervising Shames, Oliver, Naiman, Cline, Weyermann, and McKeever, to insure comparability of procedure and accuracy from year to year, was G. Lloyd Hayes, assistant forester on fire research. Hayes' major project was an altogether different study, which required every minute he could give to it.

By the end of the 1940 season mere inspection of the data indicated that several facts never before known to foresters, meteorologists, or ecologists, were beginning to become apparent. Naiman therefore compiled the data and for every figure found that appeared to be the least bit "out of line" he went back and rechecked and recompiled it, beginning with the accuracy of each instrument involved, checking the record on the chart against the figure copied on the compilation table, adding and averaging all doubtful figures all over again. Finally, he plotted these data in chart form and checked every plotted point against its tabulated figure.

Preliminary drafts of the nine charts shown here were then made available to the writer. In the text of this report he merely endeavors to call attention to facts which should be of value to fire control men in this region and perhaps in others. While this is in some respects a local project, general principles are always of more than local value. Professor Emmons of New York University contributed to one aspect of general interest and application. But before this contribution to knowledge could be made available to you - the reader - John LaCasse had to design a cover and copy the charts as only a trained draftsman can, and Ross Angle had to photograph them and make multilith plates. The one page of illustrations, originally made by K. D. Swan and the writer, also had to be copied on a multilith plate by Angle. Dagmar Nelson then cut the plates for the text, and Everett Steele ran them through the multilith machine, George Searight finally binding all the material into leaflet form for your convenient reference.

We, the twenty-five participants in this research project to date, hope that YOU will find something here which will help YOU to provide better forest fire control at less cost. The writer hopes that this "acknowledgement" and additional explanation may also serve to indicate the continuity of effort and the amount of labor involved in making a research project of this kind even begin to add to our knowledge.